US006301967B1

(12) **United States Patent**
Donskoy et al.

(10) **Patent No.: US 6,301,967 B1**
(45) **Date of Patent: Oct. 16, 2001**

(54) **METHOD AND APPARATUS FOR ACOUSTIC DETECTION AND LOCATION OF DEFECTS IN STRUCTURES OR ICE ON STRUCTURES**

(75) Inventors: **Dimitri M. Donskoy; Alexander M. Sutin**, both of Hoboken, NJ (US)

(73) Assignee: **The Trustees of the Stevens Institute of Technology**, Hoboken, NJ (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: **09/239,133**

(22) Filed: **Jan. 28, 1999**

Related U.S. Application Data

(60) Provisional application No. 60/073,567, filed on Feb. 3, 1998.

(51) **Int. Cl.**[7] **G01N 29/00**; G01H 13/00

(52) **U.S. Cl.** **73/579**; 73/597; 73/602

(58) **Field of Search** ..... 73/579, 583, 584, 73/587, 590, 591, 592, 596, 597, 598, 599, 602; 244/134 R, 134 F

(56) **References Cited**

U.S. PATENT DOCUMENTS

3,705,381	*	12/1972	Pipkin	340/3 R
3,898,840		8/1975	McElroy	73/67.9
4,233,843	*	11/1980	Thompson et al.	73/579
4,281,547	*	8/1981	Hinshaw et al.	73/579
4,381,674	*	5/1983	Abts	73/599
4,461,178		7/1984	Chamuel	73/599
4,502,329	*	3/1985	Fukunaga et al.	73/573
4,611,492		9/1986	Koosmann	73/579
4,689,993		9/1987	Slettemoen	73/579
4,944,185		7/1990	Clark, Jr. et al.	73/579
5,024,090	*	6/1991	Pettigrew et al.	73/572
5,144,838		9/1992	Tsuboi	73/579
5,170,666		12/1992	Larsen	73/571
5,179,860		1/1993	Tsuboi	73/579
5,206,806		4/1993	Gerardi et al.	364/424.06
5,214,960		6/1993	Tsuboi	73/579
5,284,058		2/1994	Jones	73/579
5,355,731		10/1994	Dixon et al.	73/579
5,425,272		6/1995	Rhodes et al.	73/579
5,456,114		10/1995	Liu et al.	73/597
5,520,052		5/1996	Perchersky	73/579
5,528,924		6/1996	Wajid et al.	73/24.06
5,557,969	*	9/1996	Jordan	73/592
5,621,400		4/1997	Corbi	340/962
5,650,610		7/1997	Gagnon	250/225
5,736,642		4/1998	Yost et al.	73/602
5,748,091		5/1998	Kim	340/583
5,823,474		10/1998	Nunnally	244/134

* cited by examiner

Primary Examiner—Helen Kwok
(74) *Attorney, Agent, or Firm*—Wolff & Samson

(57) **ABSTRACT**

The invention relates to a method and apparatus for nondestructive testing and evaluation of materials and mechanical structures to determine their integrity reducing contact-type flaws such as cracks, fractures, delamination, unbondings, etc. and also presence of ice on a structure. The invention employs an ultrasonic probing signal and a low frequency vibration applied to a structure tested. In a structure without flaws or ice, these signals propagate independently without any interaction. If the structure contains a defect or ice thereon, the vibration varies the contact area of the defect or ice/structure interface, modulating the phase and amplitude of the higher frequency ultrasonic probing signal passing through the structure. In the frequency domain the result of this modulation manifests itself as sideband spectral components with respect to frequency of the probe wave. This can be considered as a new signal generated by a defect, so that the defect can be detected more easily when such a signal is observed. There are three modes of detection including, vibro-modulation, impact-modulation and self-modulation. The location of defects can be determined in two modes. In a first mode defect is located by moving the low frequency signal about the structure and triggering the high frequency signal immediately after the low frequency signal. Defects can be located in a second mode with a sequence of short burst high frequency signal and a signal-processing algorithm which selects the sequences reflected from various areas of the tested structure. A defect can be quantitatively analyzed by sweeping the high frequency signal over a defined frequency range and measuring, averaging and normalizing the amplitudes of the side bands.

39 Claims, 10 Drawing Sheets